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INTRODUCTION TO VOLUNTARY EVACUATION RISK ASSESSMENT

Taking into consideration safety and security viewpoints of persons and property protection, evacuation as common protection mean is well known. Actually, object state-of-the-art comprises solutions generally based on experience gathered in countries much more affected by mass threats as Central Europe nationalities. Voluntary evacuation is treated as the most common evacuation form. Article presents the comparison of research conducted in USA and Poland defining voluntary evacuation scale as a significant risk factor. The evacuation risk influence determinants are described and risk assessment guidelines are performed. The guidelines are related to the state-of-the-art and the local Central Europe determinants.

Keywords: voluntary evacuation, evacuation scale, risk assessment

1. Introduction

In the case of emergency, there are generally two basic behaviour patterns – evacuation or sheltering in place [1], [2]. Particular countries have internal conceptions how to use these kinds of people protection measures in accordance with actual safety and security determinants. Common state-of-the-art is constituted in the great part by evacuation strategies elaborated in democratic countries most affected and experienced by mass threats on the world [3],[4],[5],[6]. Many of relevant conceptual elements are common with other countries' evacuation conceptions, including those in the Central Europe [7], [8].

Polish safety and security determinants emphasise the necessity of taking into consideration mostly the evacuation of people as a mean of protection. It is caused by considerably low level of shelters assurance. Based on the Supreme Audit Office data, only 4.37% of Polish people are secured by shelters and other properly prepared places [9].

Concluding, evacuation will be the most common people protection mean in the case of an emergency in Poland. However, the evacuation action could have complex influence on people safety and security. At one hand, it is focused on protection human life and/or health as well as possessions. At the other hand, additional threats, organizational and non-organizational could be present [10]. In both cases, holistic risk assessment is necessary. All the positive and negative influence factors should be analysed as a starting point to make a decision: "evacuate or shelter in place".

The article presents preliminary research results concerning one of the most important, organizational aspect of evacuation of people. It is the voluntary evacuation. Its scale and determinants could be treated as the basic mass evacuation risk factors. The comparison of the results of research conducted in Poland and USA is described. Those two countries were chosen from the perspective of relating evacuation determinants in the Central Europe representative and the state much more affected by mass threats. Another reason was a similarity of the object kinds of threats and methodology. An attempt at explaining the author's rescue experience is made. The experience concerns many situations, when people in danger did not want to leave their homes and evacuate. A hypothesis of similar behaviour pattern in other Central Europe countries is put forward. It could generate an additional risk related with non-reflecting local evacuation determinants in the light of the world's, evacuation state-of-the-art.

Finally, the voluntary evacuation risk assessment guidelines are performed. Based on the Polish safety and security environment, they could be useful in optimization of evacuation conceptions in other Central Europe countries.

2. Voluntary evacuation venture and phenomenon as evacuation risk factors

Evacuation is defined as a movement of people from the danger zone to safer places [11]. It could be organized, partially-organized or unorganized. Organized evacuation forces

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Table 1 Derivative evacuation threats and their importance priorities in Poland

No	Derivative threat name	Importance priority (1 - the most important threat)
1	Loss of influence for all evacuation proceeding elements	1
2	Direct danger to life for evacuating and evacuated people	2
3	Information chaos referring to improper media usage	2
4	Administration decision making delays	3
5	Communication barriers appearing, communication collapse included	3
6	Decrease of crisis management efficiency	4
7	Transport system insufficiency	4
8	Morale decline among evacuating and evacuated people	5
9	Panic	6
10	Difficulties in evacuation flows, chaotic transport included	6
11	Personal decision making delays	6

local administration to ensure transportation means for all the dedicated evacuees. Object, potential difficulties lead to consideration that much more simple protection means are desired. The voluntary evacuation appears as an example of such a mean. It can be understood as both: partially-organized and unorganized evacuation manner [12].

The voluntary evacuation definition concerns movement of people from the danger zone to safer places with the use of personal transport means as well as accommodation possibilities. Local administration activity is mostly limited to make the decision, warn people about the threat and evacuation proceeding initialization, point out evacuation directions and routes, indicate gathering places, loading points, medical points, service points, unloading points, dislocating places, accommodation places, as well as to ensure safety and security in all the evacuation phases and organizational elements (points, places, etc.) [8]. Such an activity scope characterizes partially-organized voluntary evacuation proceeding (the venture).

Referring to the unorganized evacuation manner, voluntary evacuation is understood as phenomenon of people movement from danger zone to subjectively safer places. It is personally initiated because of critically low sense of security, what forces to use personal transportation means, as well as accommodation possibilities. The subjectivism is worth to highlight. Exemplifying, people could move to unsafe places because of information lack and threat dynamism [8].

Making the conclusion, the voluntary evacuation could take two faces: partially-organized venture initiated by the local administration decision makers and unorganized, behaviour related phenomenon. In both cases, potential, derivative threats' catalogue is constituted. Table 1 presents the object breakdown [10].

The above breakdown presents only the most important derivative threats. As each of them could give rise to causative

– consecutive processes, the real catalogue would be much more complex. Since it could generate very serious consequences, the object risk assessment is required.

Taking present considerations, voluntary evacuation risk assessment should be one of the basic problematic aspects of evacuation risk assessment in general. Two questions at this stage appear [13], [14], [15]:

1. What is an unreliability measure?
2. What is a threat (effect) measure?

There are two ways of the unreliability measure assumption. At one stage, it is relatively easy to determine. It is voluntary evacuation initialization itself. This assumption reflects the experience-related fact that people do not want to evacuate in Poland, even if local administration leaders made the evacuation decisions. It does not matter if partially-organized or unorganized evacuation is taken into account. However, on the other stage, the unreliability measure could be measured as a primary threat probability. The effect measure is the voluntary evacuation scale – a percentage magnitude characterizing how many people declare to evacuate in case of emergency. Relation between the two measures constitutes the voluntary evacuation risk measure:

$$R=f(U,E) \quad (1)$$

where:

R - risk measure,

U - unreliability measure, $U = 1$, if voluntary evacuation is initiated,

E - effect measure.

The next logical question refers to potential, voluntary evacuation risk determinants. Analysis of primary threats (the threats causing the evacuation need) is necessary.

3. The voluntary evacuation in Poland and the USA

The primary threats are basic evacuation determinants. Their scale, character and potential progress have the greatest influence for the decision makers. Table 2 presents the comparison of the threats that could lead formally to evacuation in USA and Poland [8], [5], [16], [17].

The comparison reveals that the primary threats catalogue in USA is broader than in Poland. The USA procedures take into account more evacuation initiators. That is understandable in the light of actual, both national security systems' environments. They are obviously different. The differences arise on, for instance, geographical location, population, climate, resources, infrastructure and safety/security culture. However, the Polish State Crisis Management Plan contains much more threats' examples than in evacuation documents. There are (besides ones mentioned in the comparison):

- electricity supply disturbances,
- liquid fuel supply disturbances,
- gas supply disturbances,
- hurricanes,
- landslides,
- dam failures,
- droughts,
- other radiation threats,
- and others.

Most of them could be evacuation initiators. As a matter of fact, in the Instruction of the Chief of the National Civil Defense primary threats' catalogue is open. However, the identified lack could be an evacuation efficiency barrier.

American and Polish scientists made independent researches focusing on other voluntary evacuation risk determinants. They took place, in turn, in 2008-2009 and 2013-2014. The determinants' influence was reflected in voluntary evacuation scale.

The USA research was made by J. Carnegie and D. Dekand involved 3618 representative responders from chosen USA regions (7-country UASI Region, Newark Oversample, Jersey City Oversample and 14-country Non-UASI Region). The following threats were analyzed: hurricane + flooding, terroristic attack (IND, IED, dirty bomb), industrial accident: chemical plan and industrial accident: hazmat train. The results were presented at National Evacuation Conference in New Orleans, LA (February 3-5, 2010) [18].

There was an assumption of gathering in the voluntary evacuation risk group following elements: official notification and communications, individual difference variables, access to resources, social influences, risk perception (related with primary threats) and proximity of threat. Based on that, it was proven, that voluntary evacuation scale in USA is in relation with the following factors:

- high risk perception (positive influence),
- living close to disaster (positive influence),

Table 2 Comparison of catalogues containing primary threats in the light of evacuation in the USA and Poland

Evacuation in the USA	Evacuation in Poland
Flood	Flood
Forest fire	Forest fire
Urban fire	-
Hazardous Materials Incidents	Hazardous Materials Incidents
Terrorism	Terrorism
Nuclear Power Plant Accident	Radiological incident
Hurricane	-
Earthquake	-
Severe Storm	Severe Storm
Dam failure	-
Snowstorms	-
Lake Effect Snows	-
Blizzard	-
Tsunami	-
Landslide	Landslide
-	Epidemic
-	Building collapses
	Gas supply limitations
Debris flow	-

- pet(s) present at home (negative influence),
- person with specific care need living at home (negative influence),
- homeowner living more than five years at current residence (negative influence),
- low-income (negative influence),
- zero-vehicle household (negative influence),
- educational attainment high (positive influence),
- English not-primary language spoken at home (positive influence),
- married with children under 18 living at home (positive influence),
- 65 years of age or older (negative influence).

In accordance with the research methodology, the positive influence means "more likely to evacuate" and the negative influence means "less likely to evacuate".

The voluntary evacuation scale magnitude was in range of 67% (answer "Very likely" for the question: "How likely are you to voluntarily self-evacuate?") for the "Terror Attack" threat to 30% for the "Industrial Accident: Chemical Plan" threat.

According to the Polish research results, they involved answers of 1034 country-representative responders. The research was made by the Safety Research Department team (the author included). The following threats were analyzed: flooding, forest fire, terrorist attack, hurricane and industrial accident: hazmat car tank. The results were enclosed in a statutory scientific report:

“Public Space Research – Scale and Influence of Voluntary Evacuation of People on Mass Evacuation” (number: S/E-422/5/13) at the Main School of Fire Service in Warsaw (Poland) in December 15, 2013 [19].

There was an assumption of gathering in the voluntary evacuation risk group the same elements as in the previous research, namely: official notification and communications, individual difference variables, access to resources, social influences, risk perception (related with primary threats) and proximity of threat. Based on that, it was proven, that voluntary evacuation scale in Poland is in relation with following factors:

- high risk perception (complex influence),
- living close to disaster (complex influence),
- emergency communicates in radio said by local authorities (positive in the case of women, lonely people, village and small towns' inhabitants),
- previous mass threat experience (positive influence),
- excluding information from different information sources (negative influence in the case of the biggest towns' inhabitants),
- clear and firm activities of local authorities and public services (positive influence in case of the youngest, maximum 20 years old responders),
- living in the middle-size town (positive influence for forest fires),
- non-alone living (positive influence for all the threats quite far from home),

In accordance with the research methodology, the positive influence means “decision of voluntary evacuation” and the negative influence means “decision of sheltering in place”. The complex influences of risk perception and living close to disaster are exemplified by the following premises:

- 65 years of age or older inhabitants will more likely decide to evacuate in the case of the flood wave expected in 3 hours,
- 36-50 years of age inhabitants will less likely evacuate in the case of the flood wave expected in 0.5 h,
- women will more likely make the voluntary evacuation decision in case of weather warning concerning a hurricane likely to occur in 5 hours.

The premises could be explained by the Polish safety behavior patterns. Elderly inhabitants see their chance to voluntary evacuation owing to sufficient evacuation time (3 hours was the longest period with respect to the two others, i.e. 1 hour and 0.5 hour). The middle-aged inhabitants feel responsible for their possessions, especially in the face of a very short time between the risk perception and the threat coming. As far as the weather warning is concerned, women behavior is similar to the elderly inhabitants behavior pattern in the case of the flood threat. The analogy to voluntary evacuation decision in relation with sufficient evacuation time is observed.

The voluntary evacuation scale magnitude was in range of 48.5 % (answer “YES” for the question: “Will you self-evacuate?”)

for the situation: “Broken embankments, 1 hour to flooding wave coming” to 20.4 % for the situation “Numerous media news concerning possibility of terrorist attack without information about the attack reason”.

The comparison of American and Polish research results leads to conclusion about:

- different threats' perception in both countries (low terrorist attack threat perception in Poland and relatively high in the USA, quite different relation for flood threat),
- higher voluntary evacuation scale in the USA than in Poland (this conclusion confirms author's observation during a catastrophic Polish flood in 2010),
- differences in the voluntary evacuation risk factors and their influence on the object risk.

The conclusions made aware of the necessity to create Polish voluntary evacuation strategy and executive documents based on the Polish safety and security environmental factors. They made probable the hypothesis concerning such necessity in other Central Europe countries', as well. Practical, field experience is crucial in this venture. The object state-of-the-art ought to be treated solely as a reference point.

4. The voluntary evacuation risk assessment guidelines

Concluding the research results, creation of the voluntary evacuation risk assessment guidelines is dependent on following criteria:

- local safety and security environmental factors,
- previous practical, field experience,
- historical, behavior-determined patterns,
- voluntary evacuation scale range (in Poland: 20.4 % - 48.5 %),
- particular voluntary evacuation risk determinants.

The guidelines focus on the unreliability measure and the effect measure. As far as the first one is concerned, two ways of assessment are proper:

1. $U=1$, presumed magnitude reflecting the evacuation initialization.
2. $U \in (0,1)$, magnitude depended on local primary threat risk (especially probability).

According to the effect measure, voluntary evacuation scale determinants should be analysed as well as chosen state-of-the-art solutions implemented. Table 3 presents the suggested guidelines.

5. Conclusion

The basic volunteer risk assessment determinants were discussed in this paper. The focus was set on such risk factors as official notification and communications, individual difference variables, access to resources, social influences, risk perception (related to primary threats) and proximity of threats.

Table 3 Guidelines for voluntary evacuation risk assessment

No.	Voluntary evacuation risk assessment guidelines
1	Full primary and derivative threats' catalogues should be taken into consideration.
2	Every primary threat could give rise to causative – consecutive processes, leading to complex derivative threats. There is an opportunity to use the fault tree method and/or the event tree method to analyse risks referring to the derivative threats. Other risk assessment methods are allowed.
3	Local risk maps should be analyzed to highlight <i>U</i> magnitude as local primary threat risk (especially probability) for the second way of the risk assessment.
4	The potential evacuation zone ought to be shared into smaller parts facilitating detailed analysis of evacuees social structure and make possible an individualization of local voluntary evacuation scales' magnitudes.
5	Partially-organized and non-organized voluntary evacuation can both encompass maximum of 50 % of average (statistical representative) population. Results of the social structure determining the voluntary evacuation scale should be implemented.
6	The public evacuation means (cars, buses, trains, planes, boats, etc.) for at least 20 % of potential evacuees by the local administration are to be ensured. However, evacuation means' resources for 50 % of the local population are desired. Object lack is the next risk factor.
7	The warning time is a crucial voluntary evacuation determinant. The risk assessment ought to be based on 3 time-related scenarios: 1. Enough time to protect possessions and evacuate, 2. Enough time to evacuate, 3. Not enough time to evacuate.
8	The assessment should include scenarios with use of the local and/or public media to warn inhabitants by the local authorities.
9	Voluntary evacuation risk assessment results ought to be gathered and presented on risk maps as integral elements of local crisis management plans.
10	The assessment results should be tracked as helpful, decision support tips.

Differences between voluntary evacuation risk determinants in USA and Poland were proven. They have their sources in the local safety and security environments. The first conclusion is that the primary threats catalogue in USA is broader than in Poland. This fact constitutes the broader evacuation initiators group as well. Besides that, differences in magnitudes of voluntary evacuation scales in both countries were identified. In general, voluntary evacuation is not so common evacuation form in Poland than in the USA. One needs to emphasize, that this conclusion is opposite to the actual Polish evacuation conception. It seems to explain author's operational experience concerning situations, when people in danger did not want to leave their homes and evacuate.

Based on the Polish research and the comparison results, the guidelines for the voluntary evacuation risk assessment were

elaborated. They include general directions for the assessment person who needs to take into account local risk determinants, using the state-of-the-art only as the additional solutions' source. Besides that, they could be useful reference point in creation of evacuation conceptions in other Central Europe nationalities.

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